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ALUMINUM SST ALLOYS EVALUATED

Recently reported are the results of an evaluation of the thermal stability of three wrought-aluminum alloys after long-time elevated-temperature exposure.(1) The alloys evaluated were the two American-made materials, clad 2024-T81 and 2020-T6 and one British-made material, clad RR58. The RR58 alloy is equivalent to U. S. Alloy 2618, and, under the material designation CM001, is used as the principal material of construction in the Concorde supersonic transport. The evaluation included the determination of the effect of exposures of up to 22,000 hours at 250 and 300 F on tensile and notched-tensile properties; creep tests for times up to 18,000 hours at 250, 300, or 350 F; the determination of tensile and notched-tensile properties at -110, room temperature, 200, 250, 300, 350, and 400 F; and the examination of microstructures after exposure at 250 and 300 F for 22,000 hours. Some of the results reported in this program are indicated in Figures 1 and 2.

The conclusions drawn are that, in the 250 to 350 F range, the properties of the given materials change at rates characteristic of each alloy. The most striking feature of both Figures 1 and 2 is the relatively rapid decrease in property values by 2020-T6 at temperatures above 250 F. Alloy 2024-T81 appears superior to the other two alloys in creep strength at temperatures above about 275 F, and superior in tensile strength after 20,000 hours' exposure at 300 F.

A recent Soviet article indicates that an alloy equivalent to Alloy 2020 is used in constructing the Soviet SST, the TU-144.(2) Although no specific data are given, the article states that the Soviet alloy is used in an averaged condition to avoid "embrittlement" during service, with an acceptance of a somewhat reduced original tensile strength.

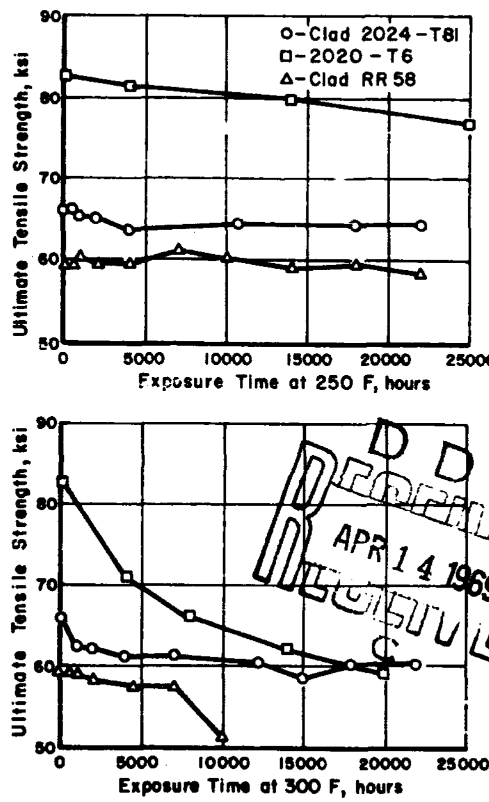

FIGURE 1. EFFECT OF ELEVATED-TEMPERATURE EXPOSURE ON THE ROOM-TEMPERATURE TENSILE PROPERTIES OF ALUMINUM ALLOYS(1)

PROTOTYPE DEEP-DIVING ALUMINUM HULL TESTED

The Naval Ship Research and Development Center has fabricated and pressure tested two models, one 16.5 inches, and the other 60 inches in diameter, representing hulls capable of diving to a depth of 5000 feet.(3) These hulls were designated composite hulls. In this design, a series of rings or cylindrical segments, which carry the load of compressive forces, form an inner hull; a relatively thin, weldable skin on the outside provides watertightness. This design approach removes the criteria of weldability from the major load-bearing elements, and allows the choice of material on the basis of strength. The outer skin is selected on the bases of weldability and corrosion resistance.

The rings used in both prototypes were ring rolled and/or forged of Alloy 7079 and heat treated to the T6 temper in the smaller model and T652 temper in the larger model. Skins were 5086-H32 for the smaller model and 5456-H34 for the larger. Models were subjected to 5000 pressure cycles and then tested to failure.

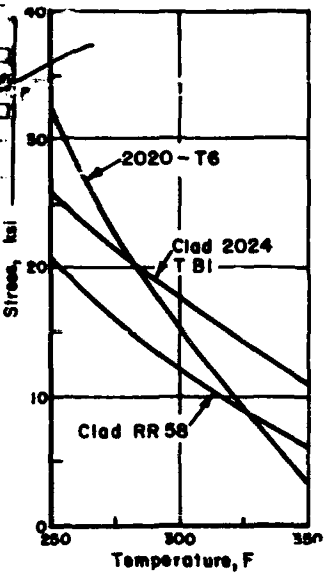

FIGURE 2. STRESS TO PRODUCE 0.1% CREEP STRAIN IN 10,000 HOURS(1)

The important conclusions of the study were that the composite aluminum-hull design constituted an efficient structure, but identified the following problem areas:

(1) The design and construction of "penetrations", i.e., ports through the hull, should be improved in view of the fatigue cracking observed in the outer skin material.

(2) Welding of the outer skin was hampered by the necessity of not overheating the internal-hull rings enough to degrade their mechanical properties.

(3) These tests (made in oil) gave no indication of the salt-water stress-corrosion behavior of the 7039 alloy inner-hull material. Such an atmosphere may be encountered in service.

HIGH-STRENGTH, CORROSION-RESISTANT TEMPER OF ALLOY 7075

A method of heat treatment said to produce a high-strength and corrosion-resistant condition in Alloy 7075 is claimed by an NASA Tech Brief originating at Tyco Labs.(4) The new heat treatment was described as follows:

1 hour at 900 F, quench in oil at 240 F
24 hours at 250 F, air cool
Up to 18 hours at 325 F.

The tensile yield strengths of various tempers were given as 73 ksi for T6 temper, 63 ksi for T73 temper, and 73 ksi forthe new temper. No comparative corrosion data were given in the tech brief, but the proposed heat treatment apparently produces corrosion resistance comparable to that of the T73 temper, i.e., not susceptible to stress-corrosion cracking.

EFFECT OF SILVER ADDITIONS ON CASTING ALLOYS

P-3

The effects of silver additions on two commercial aluminum casting alloys were studied at Rock Island Arsenal.(5) The investigation was focused on current commercial alloys rather than on high-purity or premium-quality-type alloys. Preliminary studies of a number of commercially available aluminum casting alloys such as 220, Almag 35, 356, A356, C355, 195, 40E, and Precedent 71 led to the further studies of the latter two alloys and composition variations of each. The compositions of four alloys in this study are listed in Table 1, and the effects of silver additions are shown by the data in Table 2. Thus, in each of the alloys, the silver addition was found to raise strengths by a significant increment.

TABLE 1. CHEMICAL COMPOSITION OF ALLOYS(5)

Element	Precedent 71A	Modified Precedent 71A	40E	High-Purity 40E
Magnesium	0-87	1.25	0.55	0.70
Zinc	6.7	6.7	5.75	5.75
Chromium	0.09	- -	0.42	0.30
Titanium	0.15	- -	0.19	0.16
Iron	0.08	- -	0.27	0.05
Silicon	0.07	- -	0.12	0.08
Copper	- -	- -	<0.01	<0.01
Manganese	- -	- -	<0.02	0.01
Aluminum	Balance	- -	Balance	Balance

TABLE 2. EFFECT OF SILVER ADDITIONS ON TENSILE PROPERTIES OF SEPARATELY CAST TEST BARS(5)

Alloy	Silver Addition, percent	Ultimate Tensile Strength, ksi	Tensile Yield Strength, ksi	Elongation, percent
Precedent 71A(a)	0	41.2	34.2	8.5
	0.3	50.8	43.6	9.1
Modified Precedent 71A(b)	0	40.6	40.6	1.4
	0.3	53.8	50.0	4.0
40E(b)	0	27.1	12.9	19.8
	0.3	43.6	35.2	9.0
High Purity 40E(c)	0	28.4	19.9	15.8
	0.3	40.4	33.3	10.5

(a) Aged 15 hours at 300 F.
(b) Aged 8 hours at 300 F.
(c) Aged 3 hours at 300 F.

The modification of Precedent 71 alloy indicated here was one of a number studied in the program, all of which met the criteria used by the authors that the product of the zinc and magnesium contents, Zn x Mg, = 8.5. The change in the zinc-magnesium balance resulted in an increased yield strength, relative to the unmodified Precedent 71. The addition of silver further increased both strength and ductility. The work on Alloy 40E included the effects of silver additions to both ordinary and low-iron versions of the alloy. The silver addition increased the strengths of both variations of the alloy. The authors recommended the use of silver additions in Alloy 40E whenever increased yield strengths were desired.

CHARACTERISTICS OF WELDABLE ALUMINUM-ZINC-MAGNESIUM

A summary of studies of aluminum-zinc-magnesium alloys by the British Welding Research Association deals with alloy compositions, heat treatments, mechanical properties, corrosion resistance, and the interrelationships of these factors during and after welding.(6) The aluminum-zinc-magnesium alloys are discussed in terms of four groups as indicated in Table 3. The spectrum of mechanical properties possible from these various alloys are indicated in Table 4 in terms of the strength achieved by natural (room temperature) aging, and the maximum strength reported, which is achieved by artificial aging. The reported studies identified specific metallurgical problems associated with the welding of the aluminum-zinc-magnesium alloys: hot cracking, embrittlement in the heat-affected zone, and the susceptibility of the joint area to stress-corrosion cracking. The most effective measure found for reducing hot cracking was the achievement of proper magnesium contents in the weld. Filler materials with magnesium contents up to 5 percent are recommended for base materials containing less than 2.5 percent magnesium, while alloys containing more than 2.5 percent magnesium may serve as their own filler materials. In general, the authors found that brittleness arises from both high-hydrogen contents and any extreme degree of segregation of an element to grain boundaries. Important considerations mentioned by the author included: low-hydrogen-content materials should be used, base-metal material should possess the finest grain size practicable, and high total zinc and magnesium contents or additions of copper were considered to increase the liklihood of embrittlement. The authors offer hope that stress-corrosion cracking may be controllable with the selection of proper preweld and postweld heat treatments.

TABLE 3. CHARACTERISTICS OF ALUMINUM-ZINC-MAGNESIUM ALLOYS(6)

Classification	Relative Strength	Normal Use Condition	Remarks
1. Low (3%) Zinc Medium (2%) Magnesium	Low	Naturally aged	Widely used in Europe
2. High (4 1/2-5%) Zinc Low (1-1-1/2%) Magnesium	Moderate	Naturally aged	Used in structural and transparent application in Europe
3. Medium (4%) Zinc Medium (2%) Magnesium	Moderate	Naturally aged	Includes U. S. Alloy 7039
4. High (4-5%) Zinc High (2-1/2%-3%) Magnesium	Highest	Artificially aged	Includes U. S. Alloy 7039

TABLE 4. TENSILE STRENGTHS OF ALUMINUM-ZINC-MAGNESIUM ALLOYS(6)

Nominal Composition, percent		Aging Treatment		Ultimate Tensile Strength, ksi	Tensile Yield Strength, ksi	Elongation, percent
Zn	Mg	Temp, F	Time, hours			
3.5	2.5	Naturally aged		53.7	31.3	16
3.5	2.5	212 300	32 16	60.7	52.4	9
4.9	1.4	Naturally aged		56.0	- -	22
5.0	1.2	212	48	67.2	51.5	10
5.0	2.7	Naturally aged		58.8	31.3	23
5.0	2.7	212 300	16 8	73.0	65.4	8

As a result of their studies, the authors propose two optimum weldable aluminum-zinc-magnesium alloy compositions: one for castings and one for wrought forms. The casting alloy composition was indicated as Al-3Zn-2Mg plus small amounts of zinc, titanium, and boron with properties as follows:

	Ultimate Tensile Strength, ksi	Tensile Yield Strength, ksi	Elongation, percent
Naturally Aged	40	19	>12
Fully Heat Treated	40	29	6

The wrought alloy proposed would have the composition Al-3.75Zn-2.25Mg-0.0 or 0.3Cu-0.2Zr-0.3Mn-0.2Cr-0.4max(Fe+Si). The option of the copper content allows the inclusion of copper where it may be desired for increased resistance to stress corrosion. Where corrosion resistance could be achieved by heat treatment, the copper would be omitted to reduce the risk of segregation and embrittlement as a result of welding.

OTHER CURRENT PROGRAMS(7)

Limited information has been received by DMIC to indicate that the following programs are in progress:

A program at Frankford Arsenal on "High Strength Aluminum Alloy Shaped Castings" concerns alloys containing 4 to 7 percent zinc and 2.5 to 4.5 percent magnesium. Although composition and heat-treating variations are still bcing explored, tensile properties of 65 ksi ultimate and 57 ksi yield strengths with 15 percent elongation have been reported.

Another program at Frankford Arsenal is aimed at extending the prior findings of the beneficial effects of fine dendrite-arm spacing on mechanical properties of aluminum alloys. A prior investigation was confined to sections approximately 1/8-inch thick. The current program, by the use of internal chills and directional solidification, has achieved dendrite-arm spacings of less than 50 microns in sections as thick as 3-1/2 inches.

A program at Frankford Arsenal is continuing the development of the magnesium-yttrium alloys with the goal of a strength-to-density ratio above 1,000,000 inches. The principal avenues of development are the creation of three-component, dispersion-strengthened alloys and the utilization of thermo-mechanical treatments.

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(7) Unpublished information.

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